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EARTHQUAKE TOLERANT MATERIAL - WASTE PLASTIC FIBER ADDITIVE REINFORCEMENT

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ABSTRACT

The present paper deals with the impact of seismic shocks resistance on the strength of M15/M20 concrete. The parameters of the study include the use of Ordinary Portland Cement and waste plastic fibers arranged with different orientation. The specimen cubes were cast and cured for periods 7, 14 and 28 days under similar conditions prior to testing. The study demonstrates that the 3II waste plastic fiber mix concrete to a great extent influences the strength and failure time of concrete mix. On the basis of interpretation of the results the following conclusion was drawn. Curing for 28days plain concrete M15/M20 gave adequate compressive strength of **29.21 N/mm^2** / **36.62 N/mm2** respectively, 3II-waste Fiber mix M15/M20 concrete gave adequate compressive strength **25.95 N/mm^2** / **34.00 N/mm2** slightly less but more than the desirable limit with extended failure times. The results obtained make valuable contribution to the extension of failure time by 318 Seconds for M/15 and 72 Seconds for M/20 with reference to Seismic Vulnerability of Concrete Structures. Under this back ground, in the present work an attempt has been made to modify the structural material with waste cement bags Plastic Fiber Additive Reinforcement, which leads to extension of failure time while retaining the compressive strength within desirable limit. WPFAR concrete can be used as potentially economically viable alternative material in seismic prone zones as an eco-friendly material in construction.

KEYWORDS: Earthquake Tolerant Material (ETS), Base Isolation Devices (BID), Seismic Dampers (SD), Seismic Vulnerability of Concrete Structures (SVCS), Waste Plastic Fiber Additive Reinforcement (WPFAR)

INTRODUCTION

Earthquake is major source of natural calamity which terrified human kind since induction of earth planet. There are hundreds of small earthquakes occurring around the world every day. Some of them are so micro intensified that cannot be felt by human beings, but seismographs and other sensitive machines can record them. Every year, earthquakes take the lives of thousands of people, and destroy property worth billions. The 2010 Haiti earthquake killed over 3,16,000 people and destroyed entire cities and villages

(http://news.yahoo.com/s/nm/20110112/wl_nm/us_haiti_quake_anniversary). Designing Earthquake Resistant Structures (DERS) is indispensable. It is imperative that structures are designed to resist earthquake forces, in order to reduce the loss of life and property. The science of Earthquake Engineering and Structural Design enables to design safe structures which can safely withstand earthquakes of 4 magnitudes which releases 63095734448.019 joule of energy that lacks potential to damage concrete structures. It has been experienced that the failure of structures is mainly caused by the

earthquakes of 5 magnitudes which releases 1995262314968.9 joule of energy and more.

Since the mid 70’s New Zealand buildings have been designed for earthquake resistance with stringent building rules and some great technology advances over the last 20 years. Unfortunately, there is no such material as “earthquake shocks proof material” to use for construction activities (Cooney, 1979). It is well known fact that glass, bricks and concrete, the materials that are commonly in use, are actually not advisable materials with reference to earthquakes prone zones on account of their failure as against resulting tensile and shear forces. During the course of earthquake the structures get pushed and pulled with multiple degrees of freedom, which is very different than the usual compressive force that a structure experiences when things are normal. All though the bricks and concrete are used in addition to reinforce the structure by adding steel which add strength and flexibility to the structure when it is exposed to forces other than compression yet, the damages caused by earthquakes are enormous globally

(http://articles.architectjaved.com/earthquake_resistant_structures/concept-of-earthquake-resistant-engineering).

Earthquakes create a problem to the people who live near where they occur. There are many ways to protect human life from an earthquake; one of these is to design buildings to ‘resist’ the earthquake. Currently, two basic technologies are being used to protect buildings from damaging earthquake effects. These are Base Isolation Devices and Seismic Dampers. The idea behind base isolation is to isolate the building from the ground in such a way that earthquake motions are not transmitted up through the building or its impact is reduced to a greater extent. Seismic dampers are special devices introduced in the buildings to absorb the energy provided by the ground motion to the building (Kaptan, 2013).

A group of 27 companies in 13 countries is on a mission to research, develop and manufacture sensor-embedded textiles for use in geotechnical and masonry applications. The European Union partially funds Poly-functional Technical Textiles against Natural Hazards (POLYTECT) to find technical textiles made with carbon and glass fibers to stabilize structures damaged by earthquakes, landslides or other natural disasters. The idea is simply to make architectural structures more like the human body, and to build a skin for those structures, says Thomas B. Messervey (www.polytect.net).

Many researchers have worked on geo-synthetic fiber and its usages in the building construction Koerner, (2000), but to the knowledge of authors no attempt has yet been made in the literature to evaluate the failure times of concretes. Waste Plastic Fiber Additive Reinforcement (WPFAR) used in the present work, which plays a vital role to protect potential damaging effects caused by an earthquake to building and human life.

Under this back ground, in the present work an attempt has been made to modify the structural material with waste cement bags Plastic Fiber Additive Reinforcement, which leads to extension of failure time while retaining the compressive strength within desirable limit. WPFAR concrete can be used as potentially economically viable alternative material in seismic prone zones as an eco-friendly ETM in construction.

EXPERIMENTAL METHODOLOGY

The new code BIS-456:2000 explains the mix proportioning procedure using a typical mix design problem. The basic data required for new BIS method is similar to that of the ACI method of mix design.BIS-456:2000 is applicable to ordinary and standard concrete grades only. The durability requirements, limitations on water cement ratio and maximum cement contents are as per IS 456:2000. The requirements for selecting water cement ratio, water content and estimating coarse aggregate content and fine aggregate content have been modified accordingly. Considering that the air

content in normal concrete (non air entrained concrete) is not of much significance, the consideration of air content has been deleted. The air content is not part of IS 456:2000.

Factors to be Considered for Mix Design

The mix design grade designation giving the characteristic strength requirement of concrete. The type of cement influences the rate of development of compressive strength of concrete. Maximum nominal size of aggregates to be used in concrete may be as large as possible within the limits prescribed by IS 456:2000. The cement content is to be limited from shrinkage, cracking and creep. The workability of concrete for satisfactory placing and compaction is related to the size and shape of section, quantity and spacing of reinforcement and technique used for transportation, placing and compaction (Nataraja & Das, (2010).

RESULTS AND DISCUSSIONS

24 Nos. of cube have been casted and analyzed in the Institute's Concrete Technology laboratory on Universal Testing Machine. Test and procedures are adopted as per the IS 2386 Part 4, 1963. Results of analysis are shown in the Tables. The Tables1, 2, and 3 show the results of Standard mix confirming to the IS456 and Tables 4, 5, and 6 show the results of Design mix M20. The terms used for Cubes are P7, P14, P28, 3II, 3M and 3F are respectively representing the Seven days, Fourteen days, and Twenty Eight days as per the IS 456. While term 3II is assigned for cube arrangement of plastic fibers in a parallel manner at a distance of 5 **cm** from each layer of fibers starting at a distance of 2.5 **cm** onwards. Whereas the term 3M is assigned for cube arrangement of plastic fibers in a mesh form at a distance of 5 **cm** from each layer of fibers starting at a distance of 2.5 **cm** onwards. The term 3F is assigned for cube, arrangement of 3 **cm** long plastic fibers are randomly distributed at a distance of 5 **cm** from each layer of fibers starting at a distance of 2.5 **cm** onwards.

The effect of the different tenure of full time continuous curing on the strength of the concretes is discussed in detail as under. The strength of the concretes with different tenure of full time continuous curing is given in Table 1, 2, 3, 4, 5 and 6. The compressive strength and failure time that results through an age of 7,14 and 28 days for <25° C is illustrated in the Figure 1, 2, 3 and 4 and the compressive strength & failure time of the standard cured cube at the various test stages are summarized in the Table 1, 2, 3, 4, 5 and 6.

Table 1: Showing Result of Full Time Water Curing Only for 7 Days

S. No.	Type	Area (mm2)	Proportions Grade of mix	Age (Days)	Crushing Load (T)	Compressive Strength (N/mm^2)
1	P7	22500	1:2:4	7	52.0	22.67
2	3ll	22500	1:2:4	7	45.5	19.83
3	3M	22500	1:2:4	7	42.5	18.53
4	3F	22500	1:2:4	7	48.0	20.93

The strength of the standard mix M15 concrete cubes with full time water curing for 7 days is given in Table 1. It is evident from the observations that the compressive strength gradually builds up with an age of 7, 14, and 28 days full time continuous water curing for <25° C. The results indicate that the strength of the concretes with full time water curing only for 7 days gradually increases with number of days. The maximum strength of **22.67 N/mm^2** is developed by the concrete mix-M15 in 7 days. Whereas after 7 days, the 3II WPFAR concrete mix was found to gain **19.83 N mm^2**,

the 3M WPFAR concrete mix was found to gain **18.53 N/mm^2** and the 3F WPFAR concrete mix was found to gain **20.93 N/mm^2**.

Table 2: Showing Result of Full Time Water Curing Only for 14 Days

S. No.	Type	Area (mm2)	Proportions Grade of mix	Age (Days)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	P14	22500	1:2:4	14	61.0	26.60
2	3ll	22500	1:2:4	14	52.0	22.67
3	3M	22500	1:2:4	14	53.0	23.11
4	3F	22500	1:2:4	14	55.5	24.20

The strength of the standard mix M15 concrete cubes with full time water curing for 14 days is given in Table 2. The results indicate that the strength of the concretes with full time water curing for 14 days gradually increases with number of days. The maximum strength of **26.60 N/mm^2** is developed by the concrete mix-M15 in 14 days. Whereas after 14 days, the 3II WPFAR concrete mix was found to gain **22.67 N/mm^2**, the 3M WPFAR concrete mix was found to gain **23.11 N/mm^2** and the 3F WPFAR concrete mix was found to gain **24.20 N/mm^2**.

Table 3: Showing Result of Full Time Water Curing Only for 28 Days

Serial No.	Type	Failure Time (Sec.)	Area (mm2)	Proportions Grade of mix	Age (Days)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	P28	132	22500	1:2:4	28	67.0	29.21
2	3ll	450	22500	1:2:4	28	59.5	25.94
3	3M	422	22500	1:2:4	28	58.0	25.29
4	3F	315	22500	1:2:4	28	62.5	27.25

The strength of the standard mix M15 concrete cubes with full time water curing for 28 days is given in Table 3. The maximum strength of 29.21 **N/mm^2** is developed by the concrete mix-M15 in 28 days. Whereas after 28 days, the 3II WPFAR concrete mix was found to gain **25.94 N/mm^2**, the 3M WPFAR concrete mix was found to gain **25.29 N/mm^2** and the 3F WPFAR concrete mix was found to gain **27.25 N/mm^2**. The comparative compressive strength and failure time of P28 with respect to 3II, 3M and 3F. P28 has strength **29.21 N/mm^2** and 3ll, 3M & 3F has strength **25.94, 25.29, 27.25 N/mm^2** respectively. The failure time observed that, P28 is **132 Sec**., 3ll failure time is **450 Sec**., 3M failure time is **422 Sec**. & 3F failure time is **315 Sec**. The failure time of 3ll, 3M & 3F has found more than two times compared to P28 as shown in Figure 1.

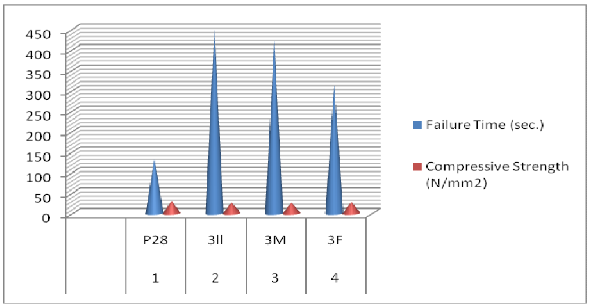

Figure 1: Showing Failure Time of 3II, 3M & 3F has Found More as Compared to P14

Table 4: Showing Result of Full Time Water Curing Only for 7 Days

Serial No.	Type	Failure Time (Sec.)	Area (mm2)	Proportions Grade of mix	Age (Days)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	P7	50	22500	1:1.75:3.5	7	52.0	22.66
2	3ll	93	22500	1:1.75:3.5	7	47.5	20.71
3	3M	87	22500	1:1.75:3.5	7	44.5	19.40
4	3F	75	22500	1:1.75:3.5	7	50.0	21.80

The strength of the design mix M20 concrete cubes with full time water curing for 7 days is given in Table 4. It is evident from the observations that the compressive strength gradually builds up with an age of 7, 14, and 28 days full time continuous water curing for <25° C. The results indicate that the strength of the concretes with full time water curing only for 7 days gradually increases with number of days. The maximum strength of **22.66 N/mm^2** is developed by the concrete mix-M15 in 7 days. Whereas after 7 days, the 3II WPFAR concrete mix was found to gain **20.71 N/mm^2**, the 3M WPFAR concrete mix was found to gain **19.40 N mm^2** and the 3F WPFAR concrete mix was found to gain **21.80 N/mm^2**. The comparative compressive strength and failure time of mixed design P7 with respect to 3II, 3M and 3F P7 has strength **22.66 N/mm^2**and 3ll, 3M & 3F has strength **20.71, 19.4, 21.80 N/mm^2** respectively. The failure time observed that, P7 is **50 Sec**. and 3II failure time is **93 Sec**., 3M failure time is **87 Sec**. & 3F failure time is **75 Sec**. The failure time of 3II, 3M & 3F has found near to two times compared to P7 as shown in Figure 2.

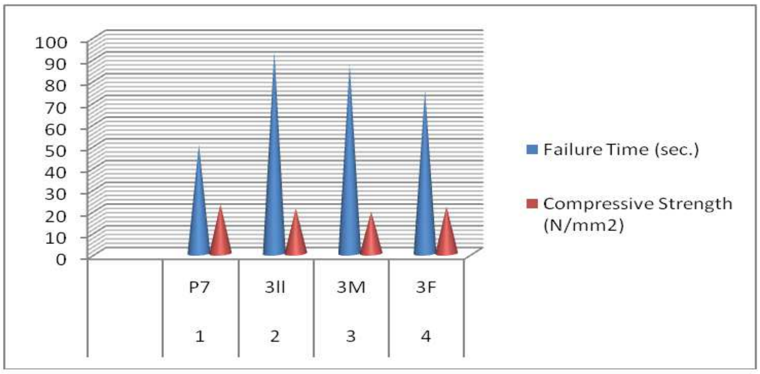

Figure 2: Showing Failure Time of 3II, 3M & 3F has Found More as Compared to P14

Table 5: Showing Result of Full Time Water Curing Only for 14 Days

S. No.	Type	Time (Sec.)	Area (mm2)	Proportions Grade of mix	Age (Days)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	P14	87	22500	1:1.75:3.5	14	64.0	27.90
2	3II	165	22500	1:1.75:3.5	14	52.5	22.89
3	3M	143	22500	1:1.75:3.5	14	50.5	22.02
4	3F	122	22500	1:1.75:3.5	14	61.5	26.81

The strength of the design mix M20 concrete cubes with full time water curing for 14 days is given in Table 5. The results indicate that the strength of the concretes with full time water curing for 14 days gradually increases with number of days. The maximum strength of **27.90 N/mm^2** is developed by the concrete M20 in 14 days. Whereas after 14 days, the 3II WPFAR concrete mix was found to gain **22.89 N/mm$^{2.}$** The 3M WPFAR concrete mix was found to gain

22.02 N/mm^2 and 3F WPFAR concrete mix was found to gain **26.81 N/mm^2**. The comparative compressive strength and failure time of mixed design P14 with respect to 3II, 3M and 3F, P14 has strength **27.9 N/mm^2** and 3II, 3M & 3F has strength 22.89, 22.02, 26.81 **N/mm^2** respectively. The failure time observed that, P14 is **87 Sec**. and 3ll failure time is **165 Sec**., 3M failure time is **143 Sec**. & 3F failure time is **122 Sec**. The failure time of 3II, 3M & 3F has found more as compared to P14 as shown in Figure 3.

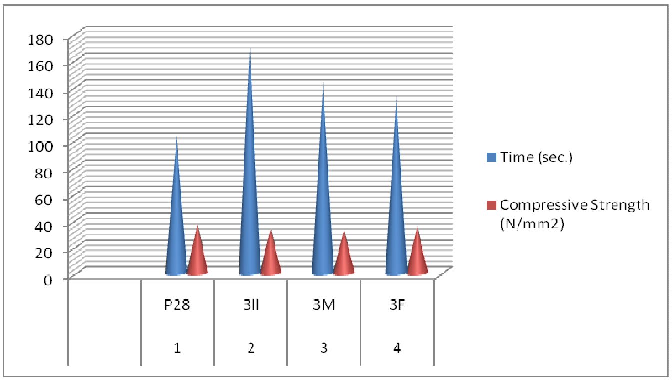

Figure 3: Showing Failure Time of 3II, 3M & 3F has Found More as Compared to P14

Table 6: Showing Result of Full Time Water Curing Only for 28 Days

S. No.	Type	Failure Time (Sec.)	Area (mm2)	Proportions Grade of mix	Age (Days)	Crushing Load (KN)	Compressive Strength (N/mm^2)
1	P28	103	22500	1:1.75:3.5	28	84.0	36.62
2	3ll	175	22500	1:1.75:3.5	28	78.0	34.00
3	3M	145	22500	1:1.75:3.5	28	75.0	32.70
4	3F	135	22500	1:1.75:3.5	28	80.5	35.10

The strength of the design mix M20 concrete cubes with full time water curing for 28 days is given in Table 6. The maximum strength of **36.62 N/mm^2** is developed by the concrete mix-M20 in 28 days. Whereas after 28 days, the 3II WPFAR concrete mix was found to gain **34.00 N/mm^{2,}** the 3M WPFAR concrete mix was found to gain **32.70 N/mm^2** $^{\text{and}}$ the 3F WPFAR concrete mix was found to gain **35.10 N/mm^2**. The comparative compressive strength and failure time of mixed design P28 with respect to 3II, 3M and 3F, P28 has strength 36.62 **N/mm^2** and 3II, 3M & 3F has strength **34.00, 32.70, 35.10 N/mm^2** respectively. The failure time observed that, P28 is **103 Sec**. and 3ll failure time is **175 Sec**., 3M failure time is **145Sec**. & 3F failure time is **135 Sec**. The failure time of 3ll, 3M & 3F has found more as compared to P28 as shown in Figure 4.

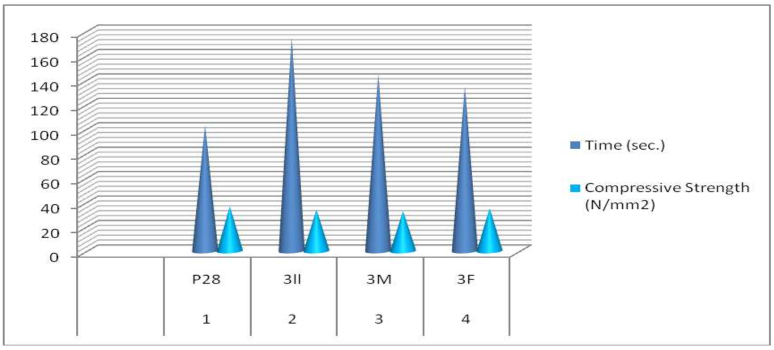

Figure 4: Showing Failure Time of 3II, 3M & 3F has Found More as Compared to P14

CONCLUSIONS

Conventional approach to earthquake resistant design of buildings is about providing the building with strength, stiffness and deformation capacity. New techniques like Energy Dissipation, Active Control Devices, Base Isolation Devices and Seismic Dampers are a more efficient and better. In present paper it observed that the Waste Plastic Fiber Additive Reinforcement 3II mix concrete is the suitable earthquake tolerant material for Seismic Vulnerability of Concrete Structures (SVCS) in Zone III, IV, and Zone V with Indian perspective, to minimize destruction of building and human life. The proposed WPFAR leads to widening of failure time while retaining the adequate compressive strength which can be used as potential eco-friendly and economically viable earthquake tolerant material for construction in seismic prone zones.

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